Comparison of Current Grid Controllers in a DG Inverter with Grid Harmonic Distortion

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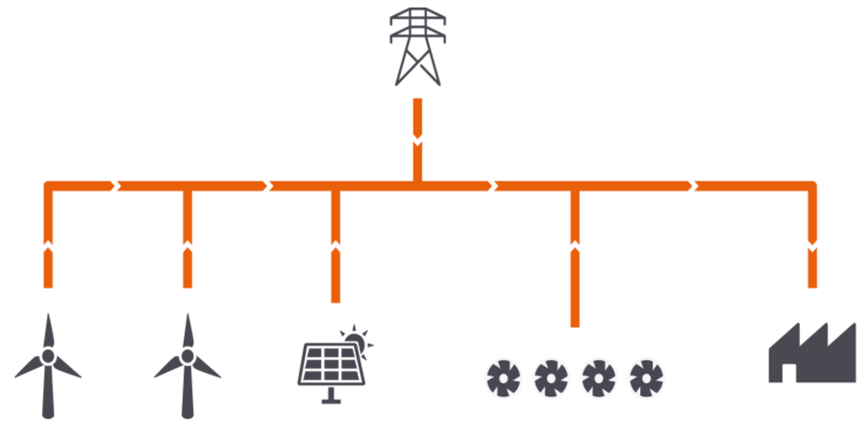
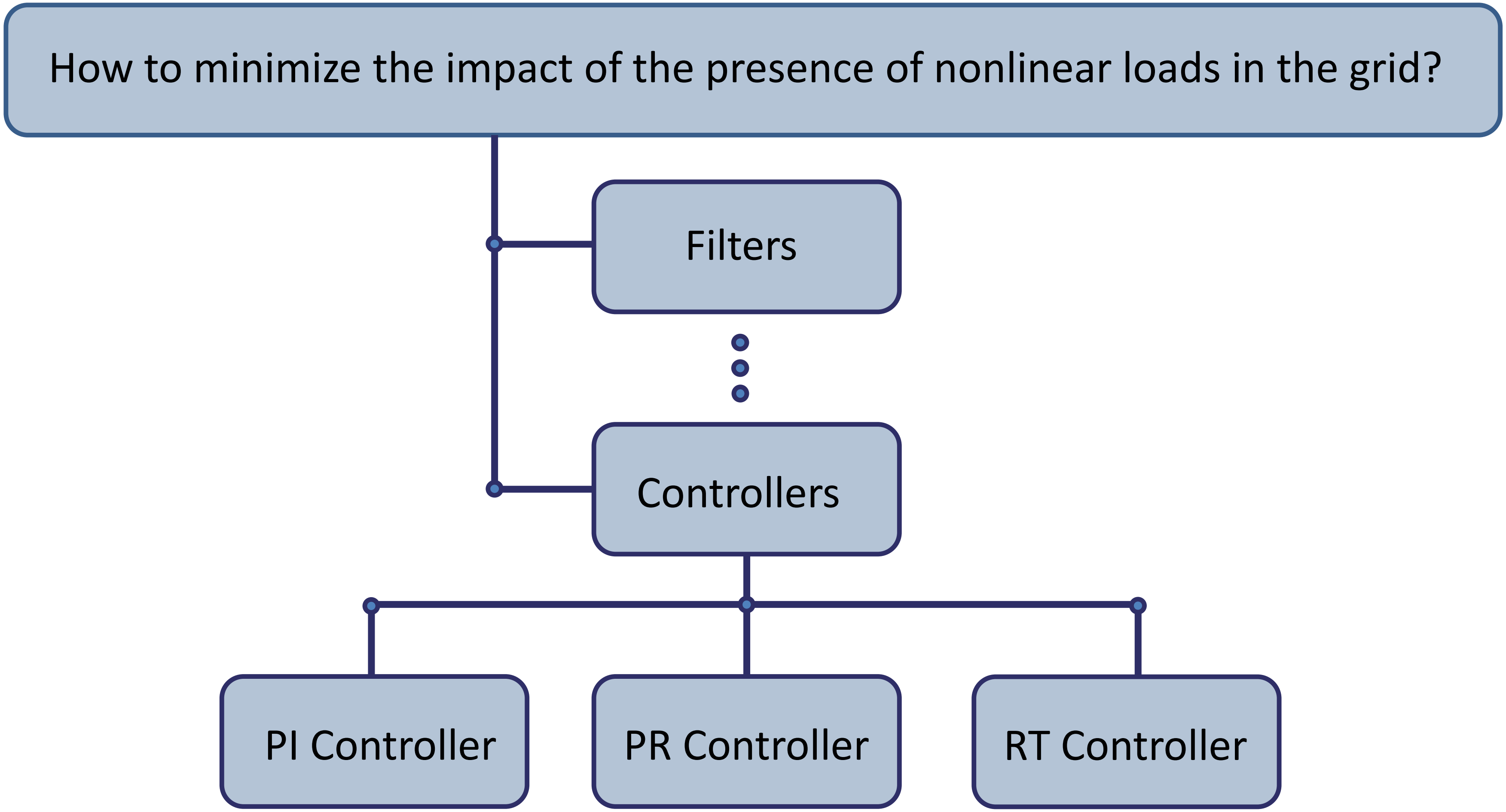
INTRODUCTION

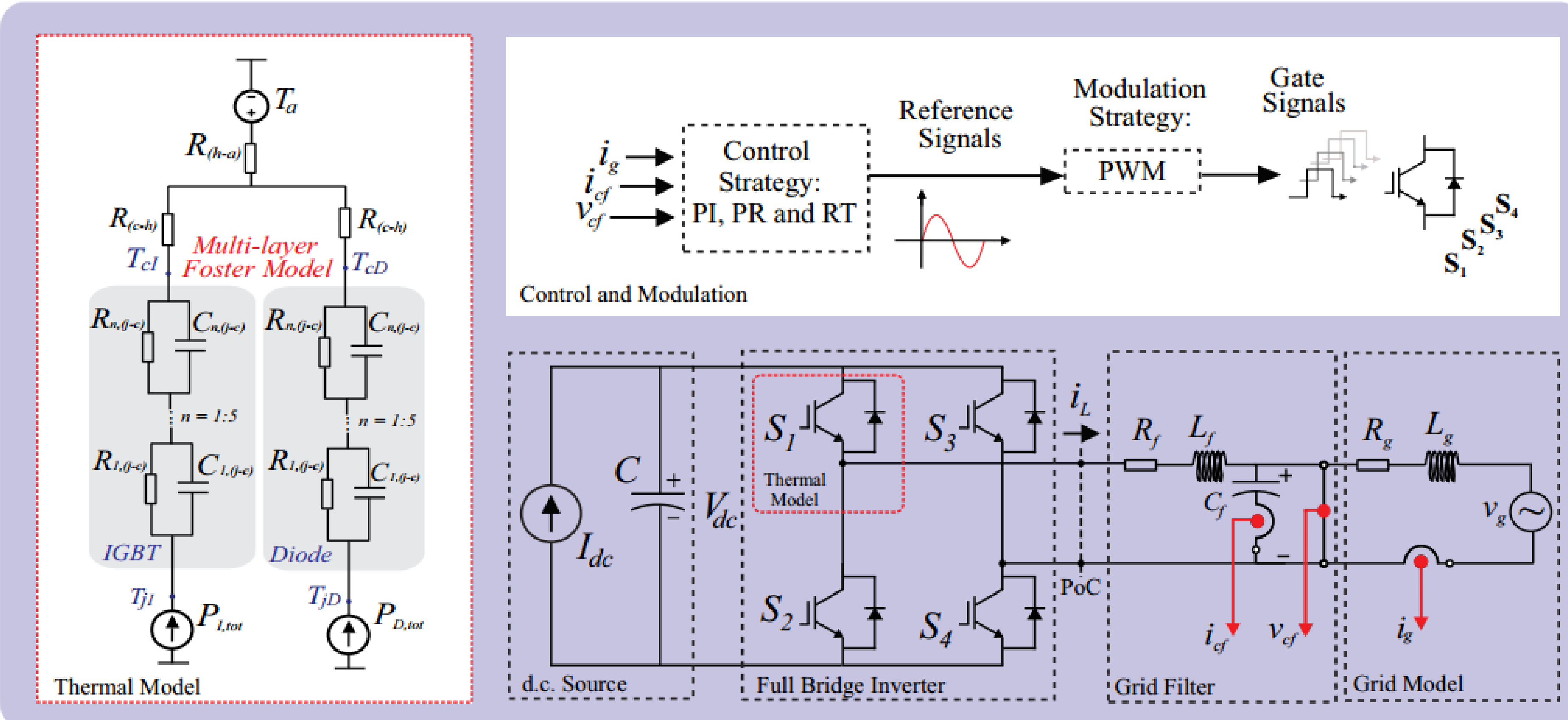
Distributed Power Generation



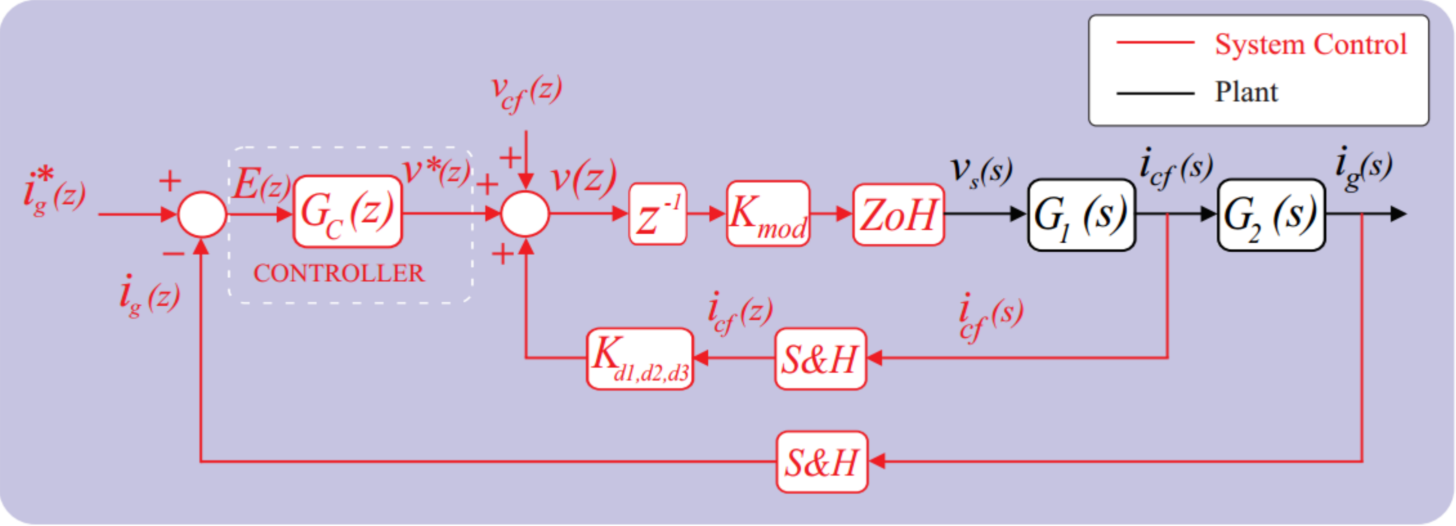
Nonlinear Loads:
Distortion in the Grid

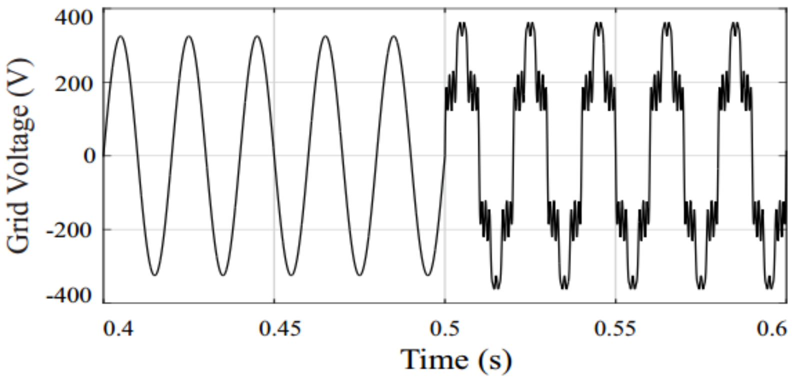

How to minimize the impact of the presence of nonlinear loads in the grid?
Filters
Controllers
PI Controller
PR Controller
RT Controller

METHODOLOGY - Single-phase DG Inverter System



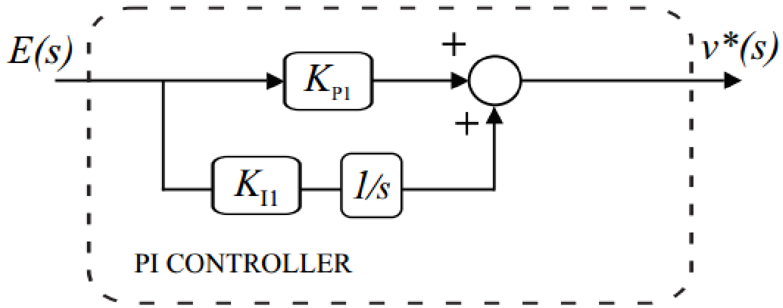
METHODOLOGY – Control Strategy

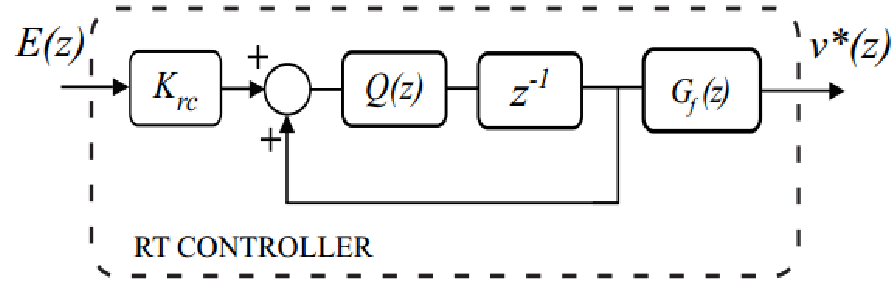


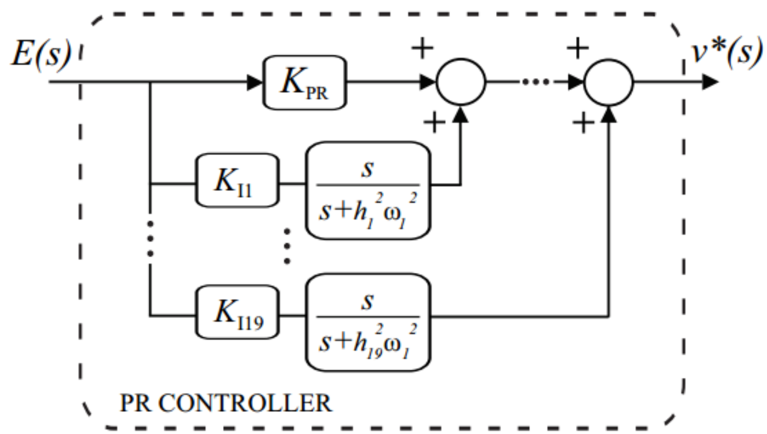


GRID VOLTAGE PROFILE

METHODOLOGY - Implemented Loop Control







METHODOLOGY - Discretization Methods

Forward

$$s = \frac{z-1}{T}$$

Backward

$$s = \frac{z-1}{zT}$$

Trapezoidal

$$s = \frac{2}{T}\frac{z-1}{z+1}$$

PI Controller

$$s = \frac{h_n w_1 (z-1)}{tg(0.5 h_n w_1 T)(z+1)}$$

Tustin pré-warping

PR Controller

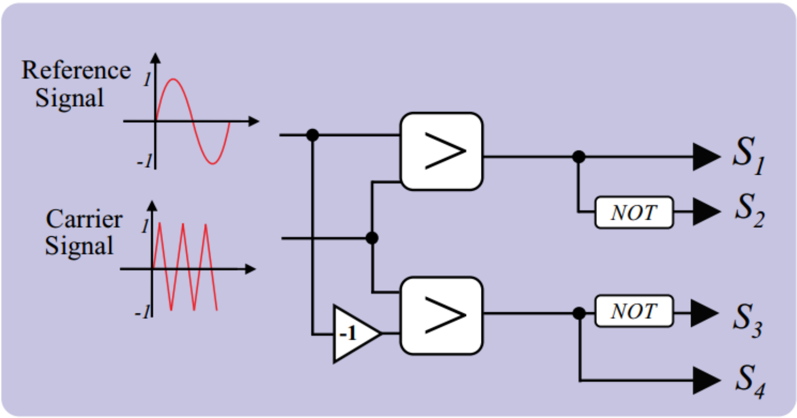
$$G_{RC}(z) = K_{rc}\frac{z^{-N}Q(z)G_f(z)}{1-z^{-N}Q(z)}$$

$$Q(z) = \alpha_1 z + \alpha_0 + \alpha_1 z^{-1}$$

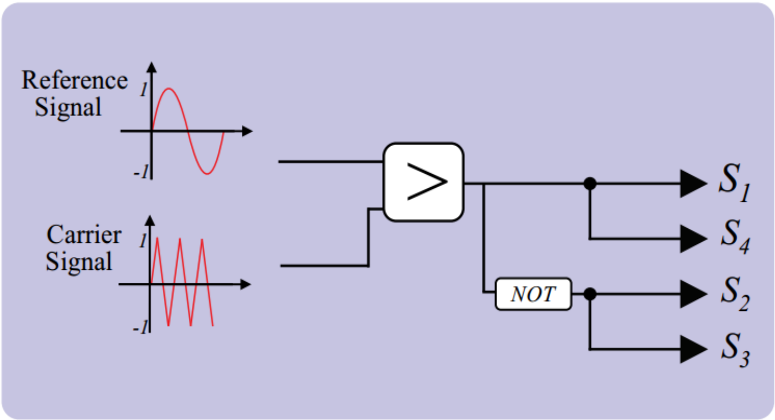
$$G_f(z) = z^m$$

RT Controller

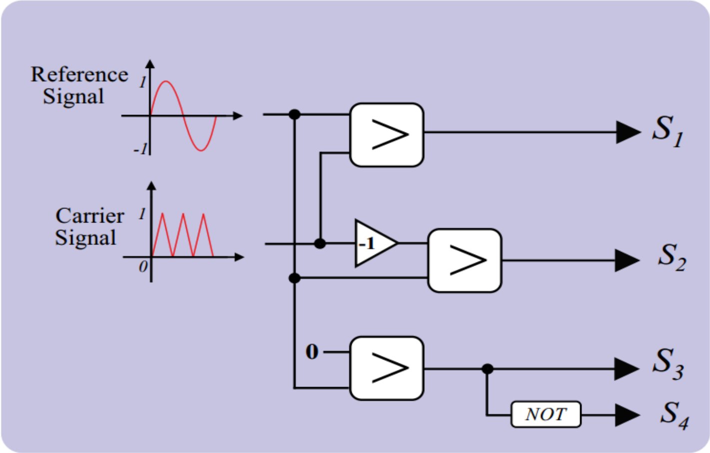
METHODOLOGY - PWM Sinusoidal Modulation



Unipolar PWM



Bipolar PWM



Hybrid PWM

METHODOLOGY – Case Study

SYSTEM PARAMETERS

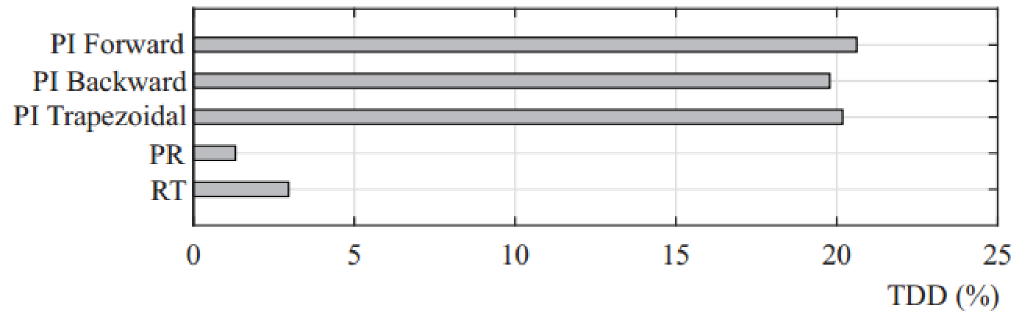
Parameters	Value
Rated Power (S_n)	$3.5\ kVA$
Grid voltage (V_g)	$230\ V$
Grid current (i_g)	$10\ A$
Line frequency (f_0)	$50\ Hz$
dc-bus voltage (V_{dc})	$400\ V$
Line Resistance (R_g)	$0.06\ \Omega$
Line Inductance (L_g)	$0.3\ mH$
Filter Capacitance (C_f)	$5\ \mu F$
Filter Inductance (L_f)	$2\ mH$
Filter Inductance-Resistance (R_{Lf})	$0.1\ \Omega$
Carrier frequency (f_{cm})	$16\ kHz$
Switching frequency (f_{sw})	$16\ kHz$
Sampling frequency (f_s)	$32\ kHz$
Carrier Magnitude (V_{cm})	$7.5\ V$
Ambient Temperature (T_a)	$313\ K$

CONTROLLERS PARAMETERS

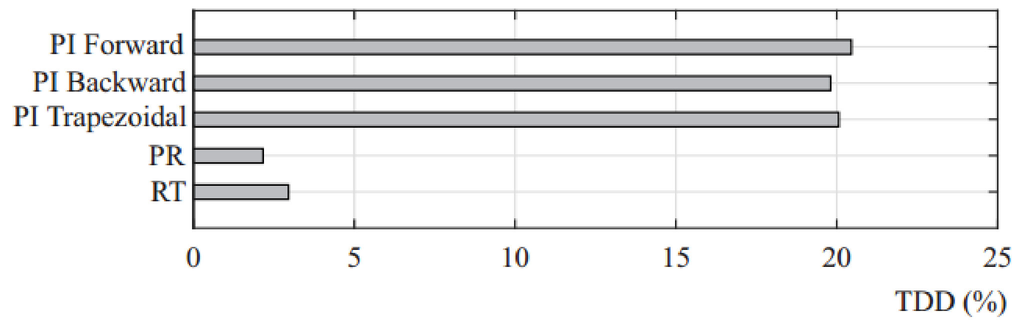
PI Controller	Value
K_{P1}	12.27
K_{I1}	8533.33
K_{d1}	14
K_{mod}	0.0187
PR Controller	**Value**
K_{PR}	11.37
K_{In} (for n $\neq$ 1)	500
K_{In} (for n = 1)	1000
K_{d2}	14
K_{mod}	0.0187
RT Controller	**Value**
K_1	12.27
K_{rc}	2
N	320
m	3
α_0	0.5
α_1	0.25
K_{d3}	14
K_{mod}	0.0187

RESULTS – Techniques Modulations: TDD Analysis

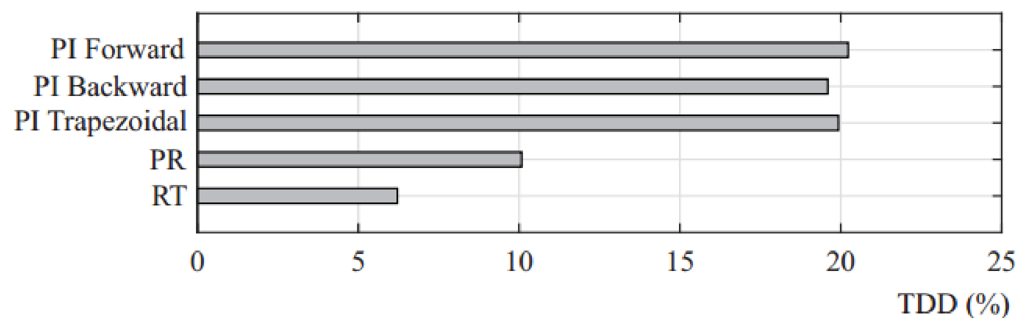
Unipolar



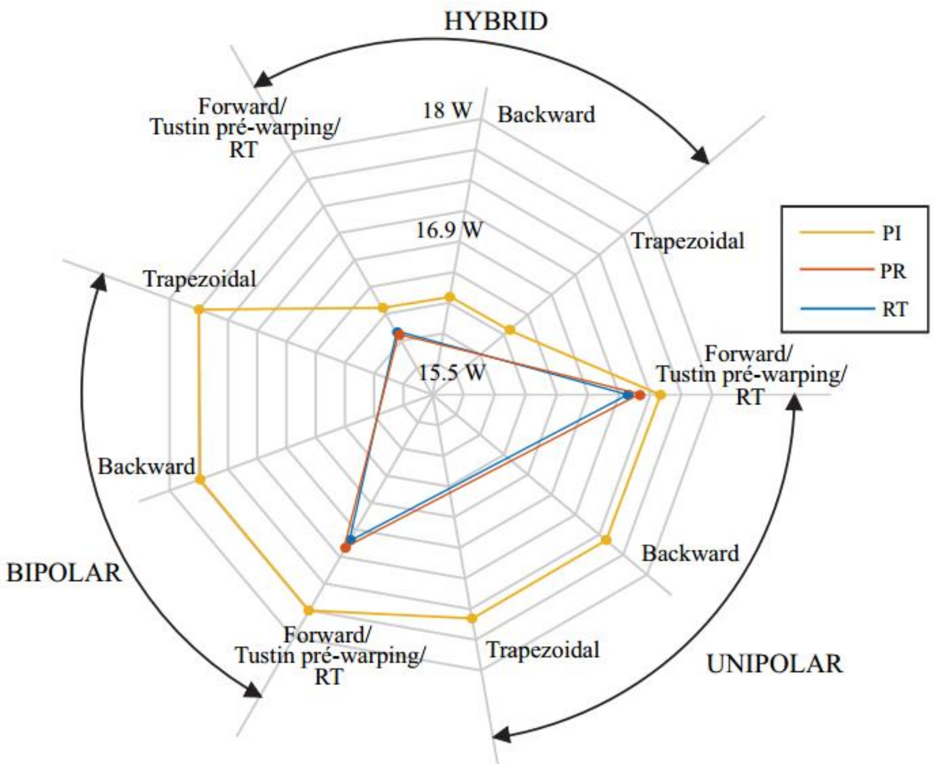
Bipolar

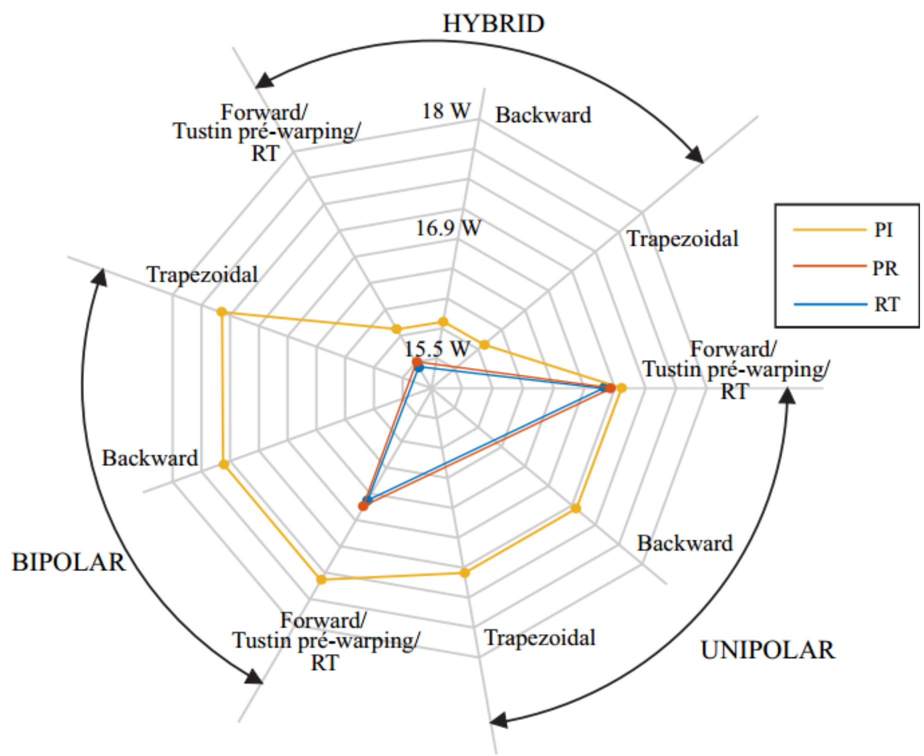


Hybrid



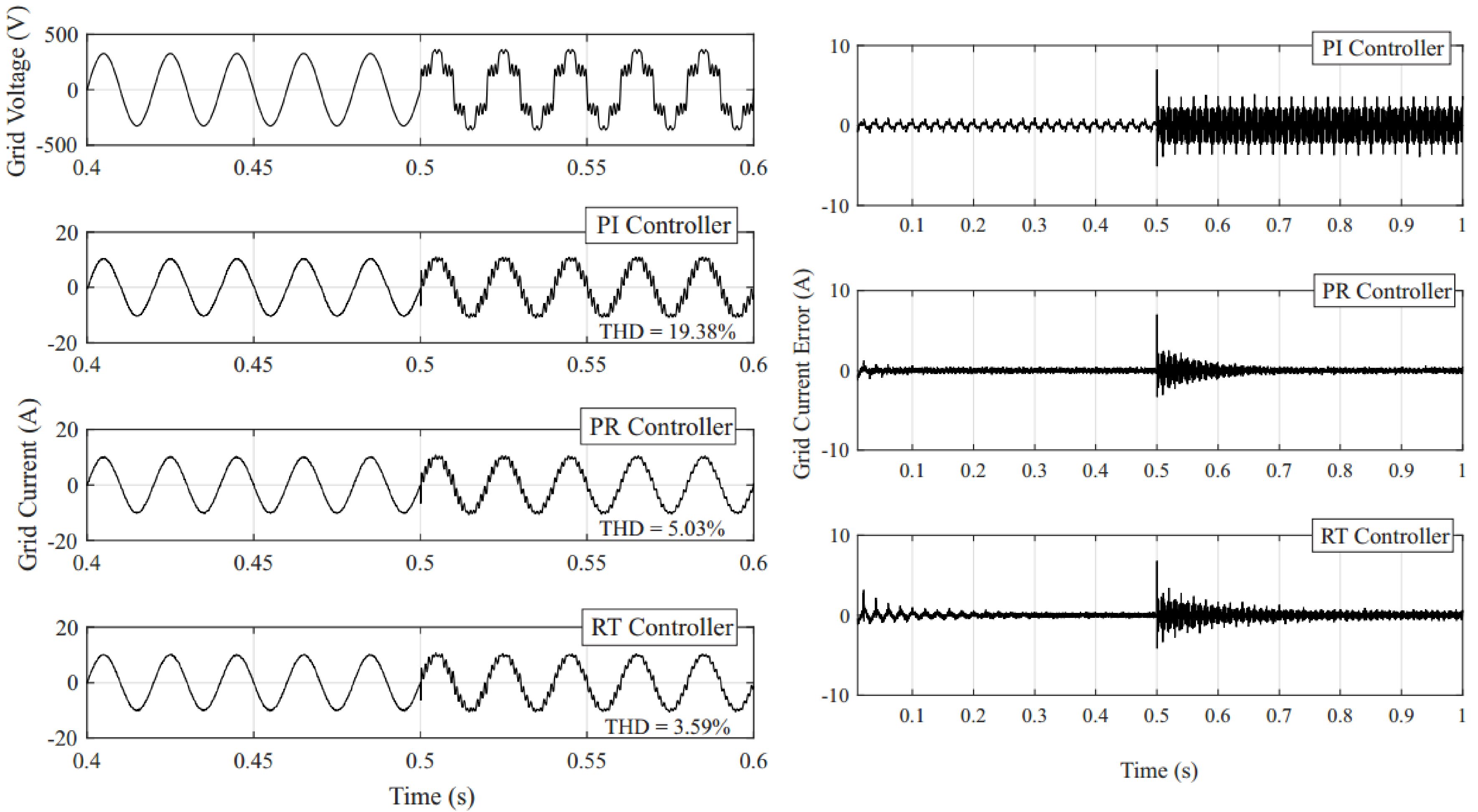
RESULTS – Power Losses





Power Losses w/ Grid Harmonic Distortion **Power Losses w/o Grid Harmonic Distortion**

RESULTS – Controllers Response

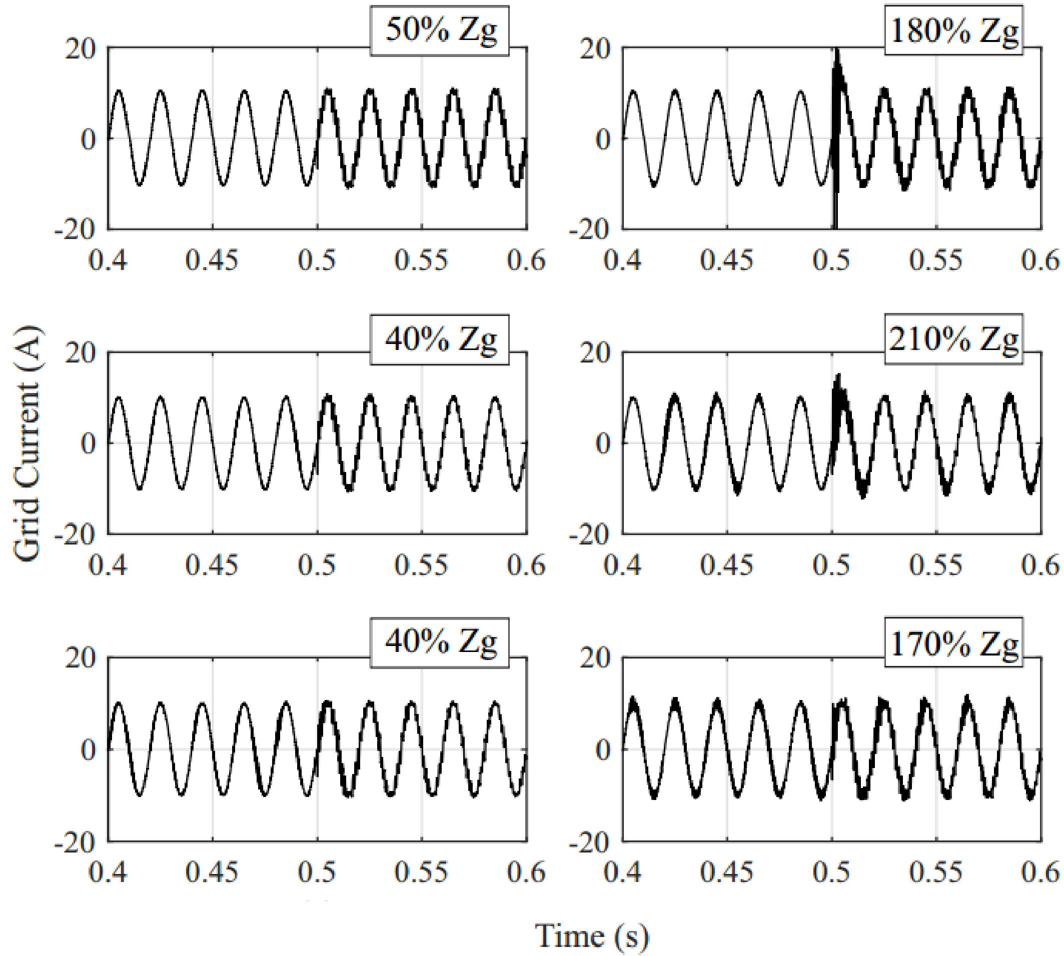


RESULTS – Short Circuit Level

PI Controller

PR Controller

RT Controller



RESULTS – Variation of the TDD (%) with the short circuit level (ϒ)

Grid Impedance

$$Z_g = R_g\gamma + j2\pi f_0 L_g \gamma$$

	Percentage of Zg and TDD							
Controller Type	γ (%)	TDD	γ (%)	TDD	γ (%)	TDD	γ (%)	TDD
PI	50	19.6785	75	19.7365	140	19.7718	180	21.4603
PR	40	1.2090	75	1.4195	140	1.6570	210	3.2759
RT	40	2.9059	75	2.91	140	3.0049	170	6.1502

CONCLUSION

- The PR and RT controllers presents the lower power losses in Hybrid modulation;
- TDD rate revealed the Hybrid modulation is a poor in grid current quality;
- The short circuit analyzes presented a lower TDD varying the short circuit factor, in PR and RT controller;
- The study revealed an excellent response of the PR and RT controllers in the grid energy quality, for unipolar modulation and hybrid modulation for PI controller;

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CAPES

FAPEMIG

Questions?!

Thank you!

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